Assessment of Reliability and Operational Issues for Integration of Renewable Generation

Energy Commission Committee Workshop

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Briefing Outline

1. Introduction
   - Literature Review
   - Stakeholders Interviewed
   - Summary of Issues
   - California Historical Experience in Integrating Resources
2. Experience of:
   - E.ON Netz (Germany)
   - Eltra (Denmark)
3. Operational and Reliability Issues for California
   - Renewables Development to Meet RPS by 2010
   - Discussion of Issues
4. Recap of Issues and Next Steps

Reports and Studies Reviewed

- Team reviewed in excess of 38 studies and reports
- Sources:
  - CEC
  - CPUC
  - National and International TSOs
  - US Government (DOE) and state governments
  - Conferences and workshops
  - Stakeholder interviews
- Review identified gaps which are included in the reliability and operational issues list

Stakeholders Interviewed

- California Independent System Operator
- California Wind Energy Collaborative
- Center for Energy Efficiency and Renewable Technology
- Imperial Irrigation District
- PPM Energy
- Pacific Gas and Electric
- Royal Institute of Technology, Sweden
- Sacramento Municipal Utility District
- San Diego Gas and Electric
- SolarGenix Energy
- Southern California Edison
- Vulcan Power

Summary List of Issues from Literature Review and Stakeholder Interviews

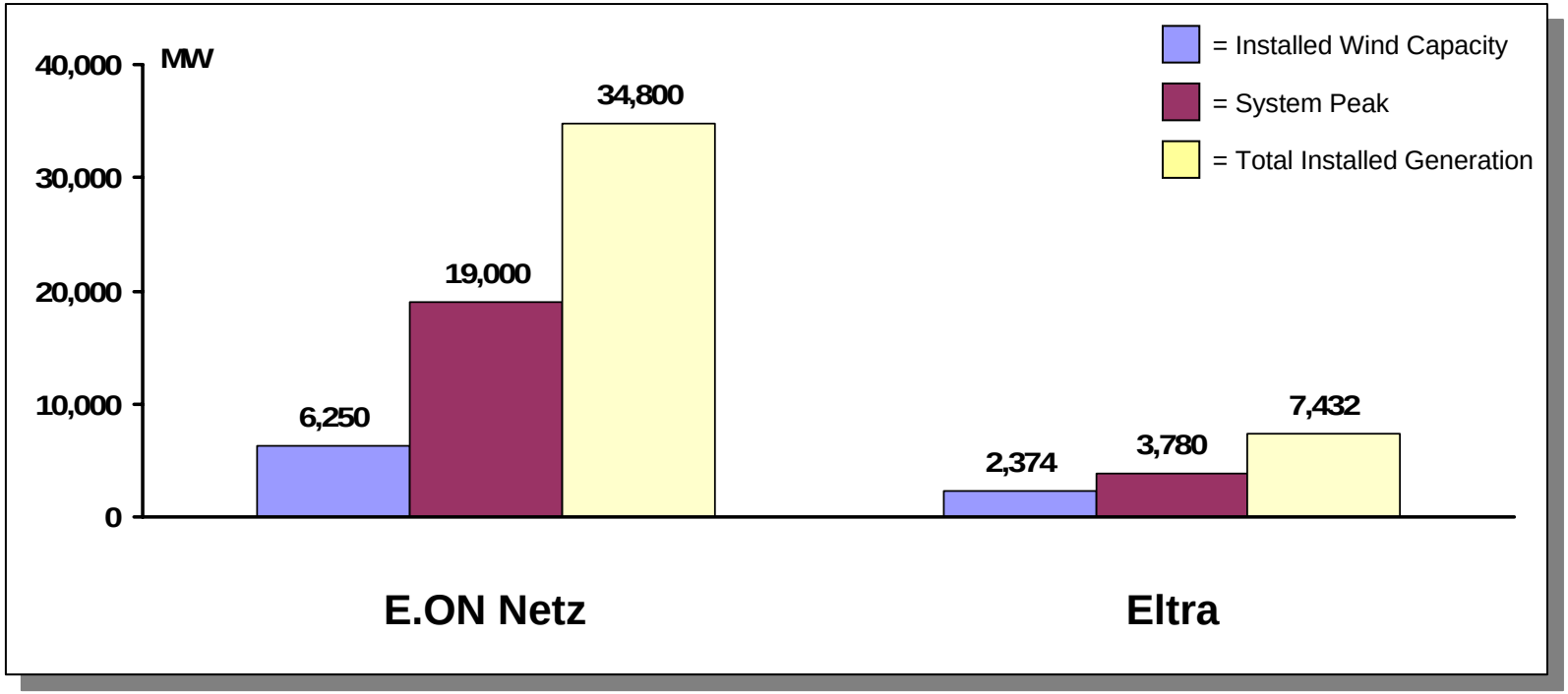
- Load Following
- Compliance with NERC Standards – CPS, DCS
- Minimum Loads
- Storage
- Reserves
- Load and Generation Forecast Variability
- Frequency Deviations Due to Intermittent Production
- Voltage Support
- Retirement of Older Plants and Reduction of Controllable Generation
- Resource Deliverability
- Transmission Import Capability
- Planning and Modeling

California Has Extensive Experience with Addressing Operational Issues Associated with Integrating New Resources and Technologies

Resources and Technologies	Operating Issues Addressed
Remote Coal Generation in 60's/70's	Dynamic Dispatch
	Base Load Operation - No Load Following
	Subsynchronous Resonance
Pacific Intertie and Other Interconnections	Reliability
	Reserve Sharing
	Transmission Ratings and Coordinated Operations
	Loop Flows
Declining Load Factors with Increased Summer Peak Usage	Daily and Weekend Cycling of Power Plants
Nuclear Generation in 80's	Base Load Operation - No Load Following or Ramping
Increased System Imports	Minimum Local Generation for Reliability and Voltage Supply
QF Integration in 80's	Minimum Loads
	No Generation Control

Experience of E.ON Netz (Germany) and Eltra (Denmark)

Overview of E.ON. Netz and Eltra System Characteristics



Wind Performance

E.ON Netz (Central Germany):

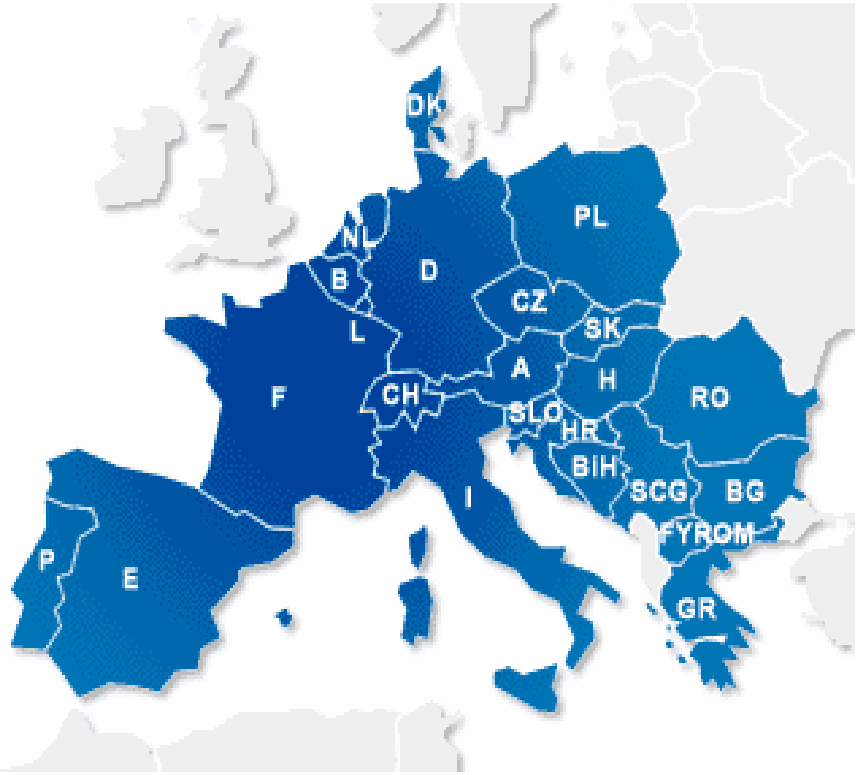
- 18% of total installed generation
- 8,500 GWh of total wind generation
- 8% of total system energy generation

Eltra (Denmark):

- 32% of total installed generation
- 4,863 GWh of total wind generation
- 23% of total system energy generation

Reserve Sharing and Imbalance Energy

- E.ON and Eltra are members of UCTE*
  - Eltra is also a member of the Nordic Pool
- UCTE network is an electrically connected synchronous grid linking Europe – 360,000 MW System
- Nordic Pool serves Scandinavian countries – 53,700 MW system
- E.ON obtains reserve sharing and imbalance energy from UCTE
- Eltra obtains reserve sharing and imbalance energy from Nordic Pool and UCTE



Source: http://www.ucte.org/

*Union for the Co-ordination of Transmission of Electricity (UCTE)

E.ON Netz and Eltra Operating Issues for Integration of Wind

- Forecast Variability
  - Near-term forecast errors of 50 to 60%
- Production Variability (E.ON Netz)
  - Contribution to daily peak load ranged from 0.1 to 32%
- Ramping (E.ON Netz)
  - 6-hour production variability of 60 to 70% of installed capacity
  - Daily production variability of 4,300 MW
- Shadow Reserves – carry reserves for up to 80% of installed wind generation
- No grid voltage support during faults
- Wind plants disconnect during grid faults – E.ON Netz experienced 60% of wind generation loss due to voltage dip in one region
- Methodologies to address issues – generation management, grid code, high reserves, interconnection support

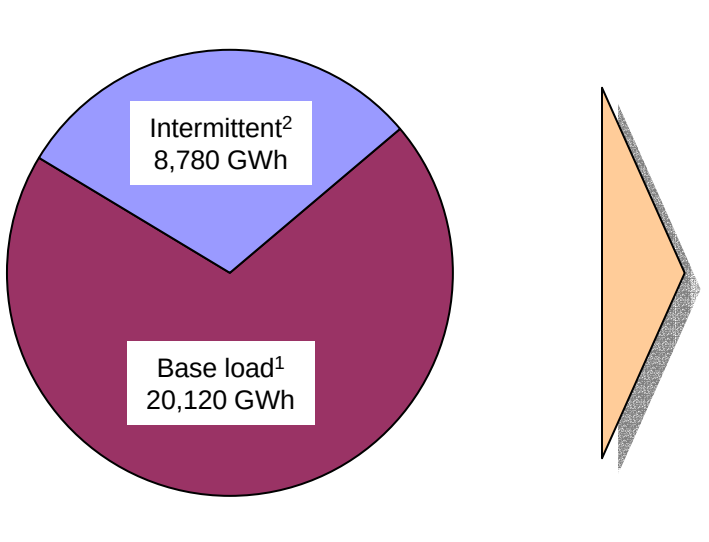
Renewable Resource Development and Operating Characteristics

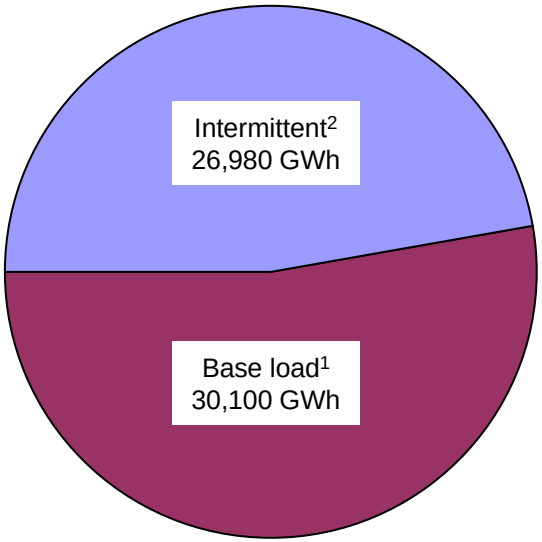
Renewable Resource Development to Meet RPS by 2010

2002
28,900 GWh

2010
57,080 GWh

Total Contribution to Energy Mix
- Intermittent 3%
- Base load 8%





Total Contribution to Energy Mix
- Intermittent 9%
- Base load 11%

% Increase from ’02 – ’10

Base Load[1]	50%
Intermittent[2]	207%

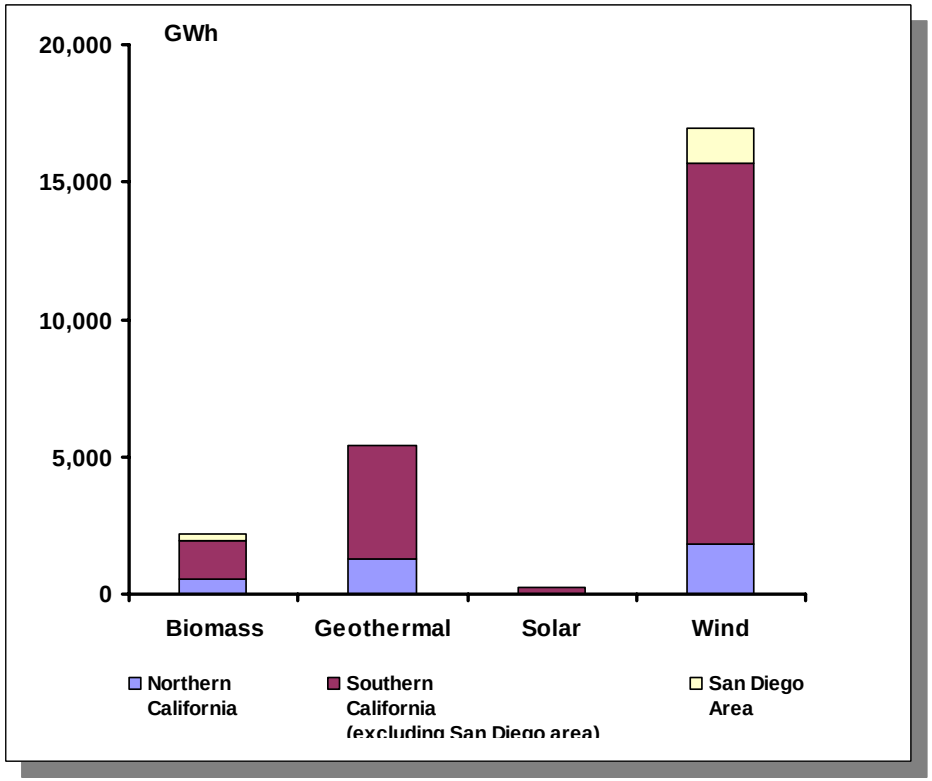
Notes:
(1) Includes biomass and geothermal resources
(2) Includes small hydro, solar, and wind resources

Sources:
CEC Renewable Development Report (500-03-080F), CEC Accelerated Renewable Energy Development (100-04-003D), and CEC Integrated Energy Policy Report 2004 Update.

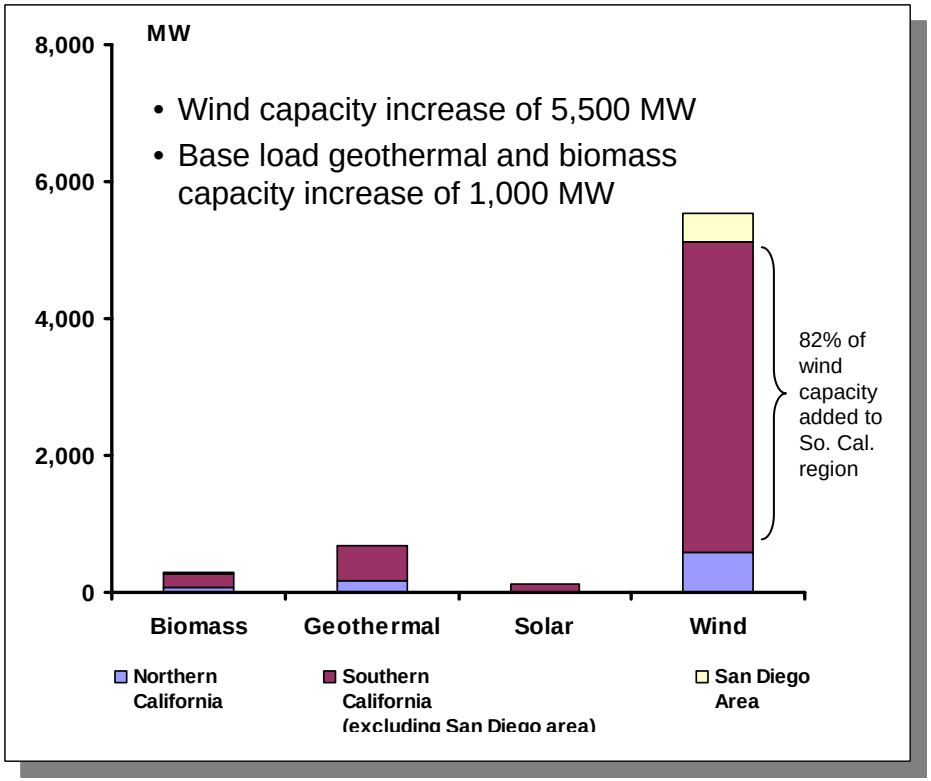
Scenario for renewable development by technology and region

Accelerated Incremental RPS Requirements Year 2010

Energy



Capacity



Notes:
Northern California = PG&E and small utilities in N. California
Southern California = SCE and small utilities in S. California (excluding San Diego area)
San Diego Area = SDG&E and Escondido utilities

Characteristics of Renewable Resources that Impact Operations

Intermittent

(Small Hydro, Solar, Wind)

- Production may not correlate with system load
- Production forecast uncertainty
- Production variability
- Limited ability to control output without curtailment
- No regulation or ramping to follow load

Base Load

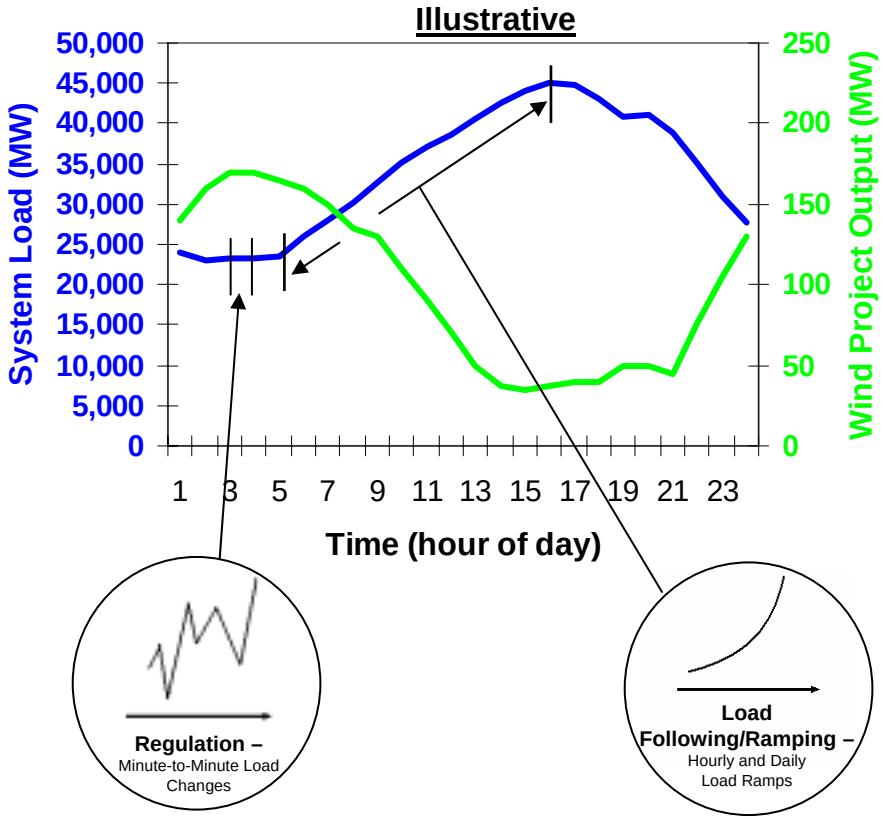
(Biomass, Geothermal)

- Round-the-clock production
- Limited ability to control output
- No regulation or ramping to follow load

Operational and Reliability Issues for California

Issue: Load Following

Description: The control area operator is responsible for ensuring that operation is within the WECC and NERC standards. This includes meeting minute-to-minute changes in both load and generation by controlling some generation on the grid to constantly balance load and generation.

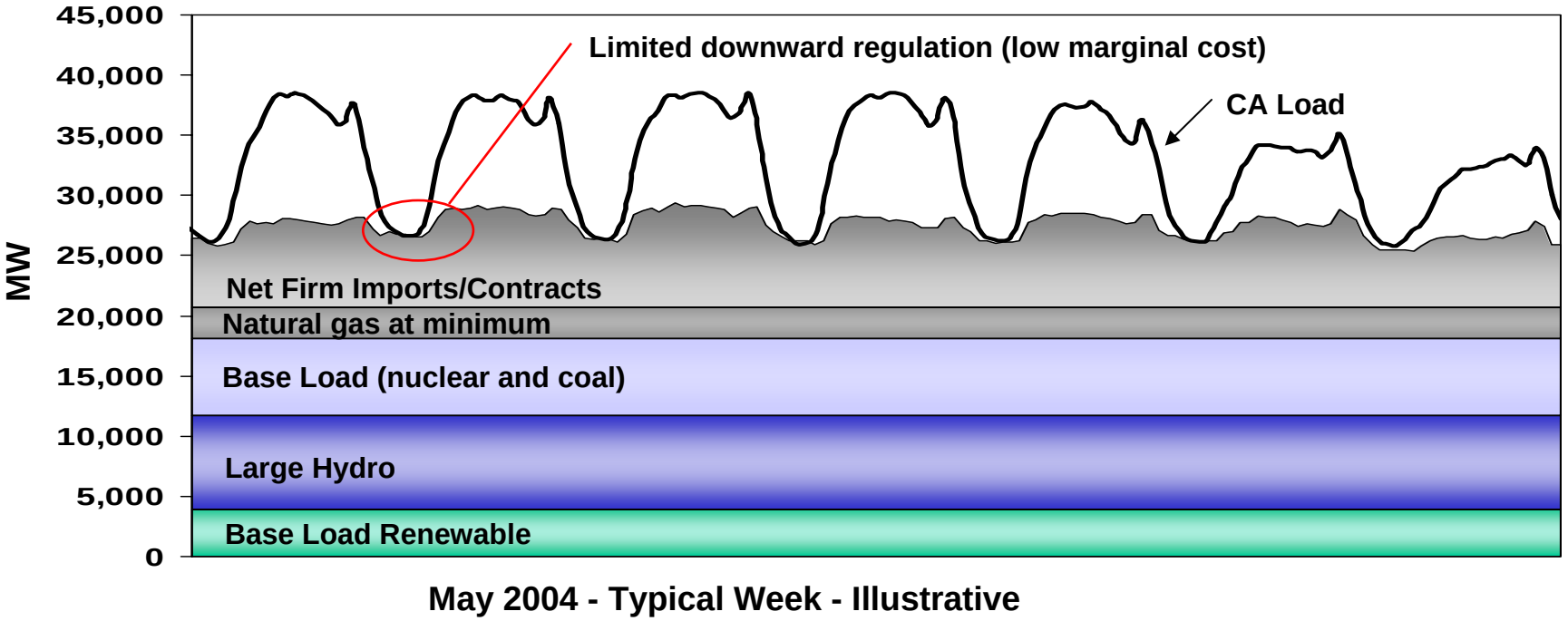


- CAISO Daily Load Ramp (9/7/04) was 21,900 MW
- The production from some intermittent renewable resources does not correlate with the system load and will increase the load following requirement.
- With 5,500 MW of wind additions, daily load ramp may increase by up to 4,000 MW

Issue: Minimum Load Condition

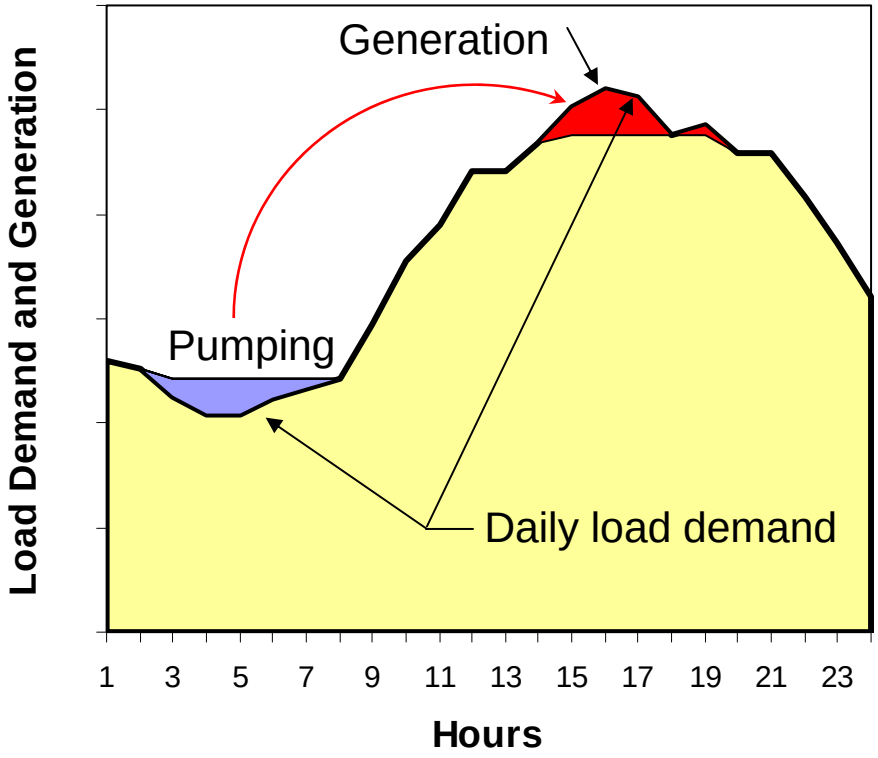
Description: High levels of off-peak energy production pose operating problems for the CAO, the TSO, and retail energy supplier.

- California currently experiences minimum load problems
- Addition of non-controllable renewable resources exacerbates minimum load issues
- Base load additions increase minimum generation by 1,000 MW; 60% wind off-peak production may add another 3,300 MW of minimum load



Issue: Storage and Load Shifting

Description: Storage has been identified as one means of improving the resource value of intermittent energy sources by shifting energy produced during off peak periods into peak load periods and mitigating minimum load impacts.



Pumped Hydro Facilities:

- Nearly 4,000 MW of existing pump storage capability in the state
- During spring runoff months:
  - Facilities are used for flow through to maximize production and avoid spill
  - Pump back generally not available
- To integrate renewables, CA needs more pumped hydro, or storage, or load shifting

Issue: Reserves

Description: The accurate determination of generating resources and reserves is essential to maintain operating margins for safe and reliable operation.

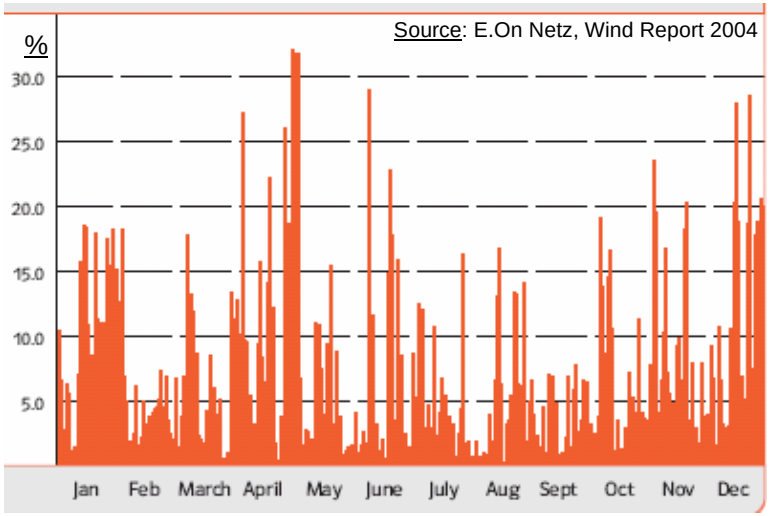
- Installed reserves capacity includes both stand-by and operating reserves
- Reserve capacity can be brought on/off-line at short notice to balance out deviations between actual/forecast of generation or load

California Reserves

- California planning reserve target is 15%
- What level of additional reserves will be required in CA to integrate renewables?

E.ON Netz experience with intermittent generation:

- For 2003, percentage contribution of wind power in covering the daily peak load varied between 0.1 and 32%
- Maintains traditional power stations (installed reserves) equivalent to 80% of the installed wind energy capacity
- Maintains operating reserve capacities amounting to 50 to 60% of the installed wind power



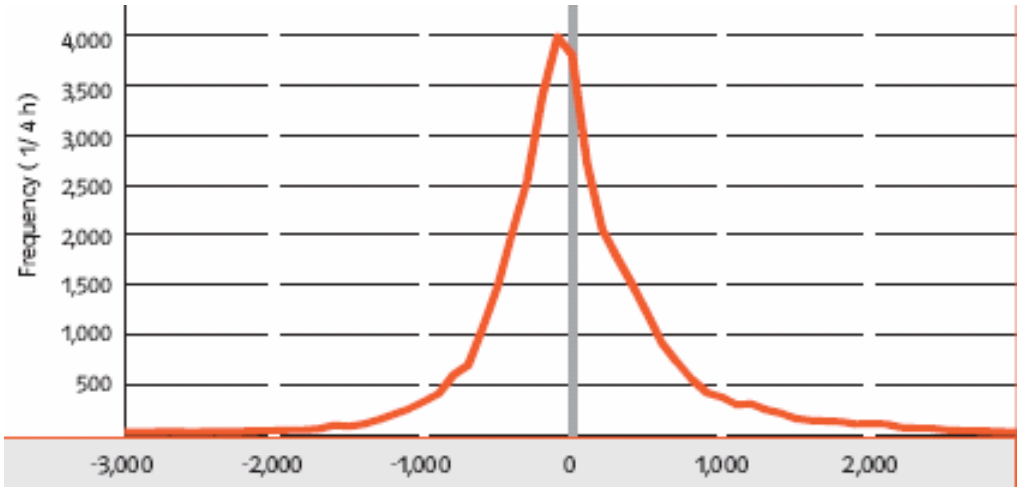
Issue: Load and Generation Forecast Variability

Description: Accurately forecasting both the hourly load and hourly generation is important in maintaining adequate resources and reserve margins for reliable operation.

International Experience

- E.ON individual hour deviations reached nearly 50% of the installed capacity of 6,250 MW
  - Average positive and negative error was 477 and -370 MW, respectively.
- Eltra's objective is to provide a more accurate forecast, while obtaining data on forecast reliability
- Both E.ON and Eltra utilized interconnections to balance the grid

E.ON Netz - 2003 Wind Generation Forecast Error



Source: E.On Netz, Wind Report 2004

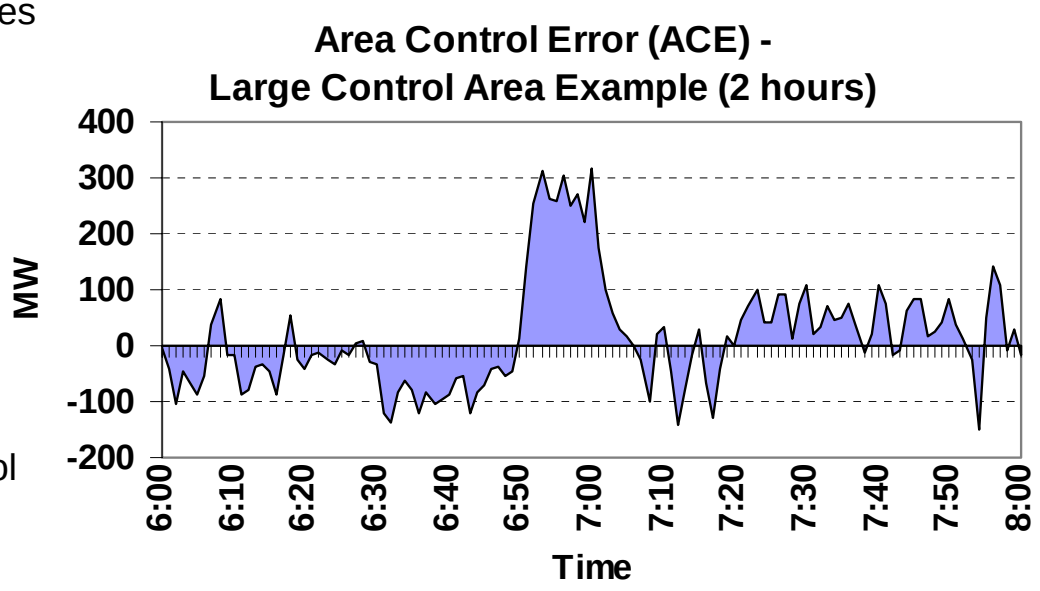
Impacts

- Forecast accuracy affects reserve requirements

Issue: NERC Control Performance Standards (CPS) and Disturbance Control Standard (DCS)

Description: NERC has established CPS to ensure that each control area diligently and effectively balances its generation with load on a continuous and consistent basis. The DCS standard requires Control Area Operators to carry sufficient contingency reserves to meet the loss of generation and transmission. Imbalances are measured in terms of Area Control Error (ACE).

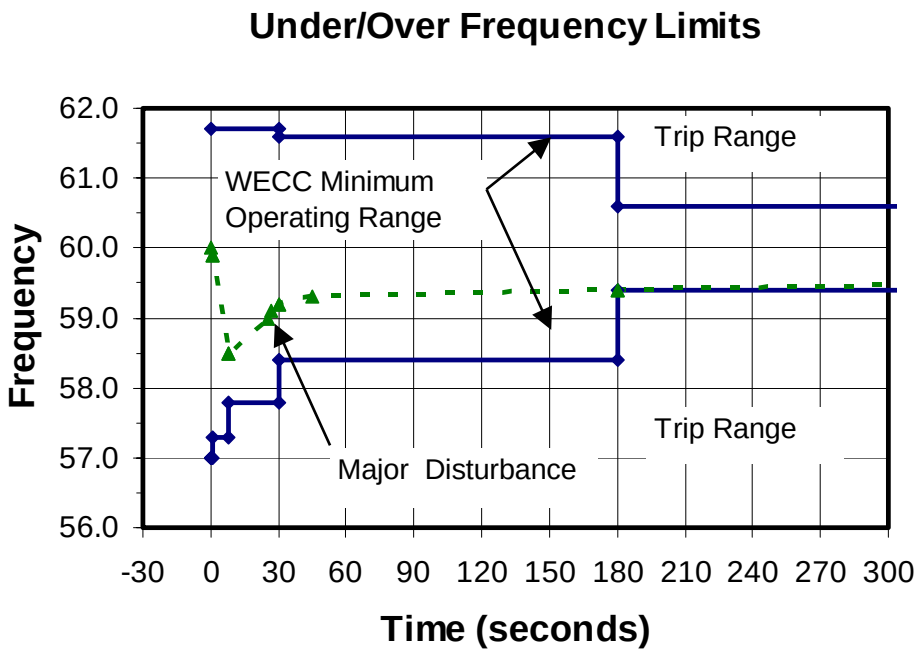
- ACE must cross zero every 10 minutes (90% minimum compliance for 10 minute periods in a month)
- ACE must cross zero in 15 minutes after a disturbance
- ACE normal range is +/- 200 to 400 MW
- Addition of large amounts of intermittent resources will require substantially more spin or load control
- Increase in ACE will impact neighboring interconnections and reliability performance



Issue: Frequency Deviations

Description: What <u>frequency ride-through</u> capability is needed to integrate renewables and assure compliance?

<u>Illustrative</u>



<u>Performance Standard</u>

- Generator must stay connected for short duration frequency dips, e.g.,
  - 45 cycle dips down to 57.0 Hz
  - 7.5 second dips to 57.3 Hz
  - 30 second dips to 57.8 Hz
  - 3 minute dips to 58.5 Hz
- Alberta ESO Wind Power Facility technical Requirements mirror the WECC Standards
- AWEA and FERC proposed standards do not address off-nominal frequency performance requirements
- E.ON Netz has adopted a standard for wind

<u>Impacts</u>

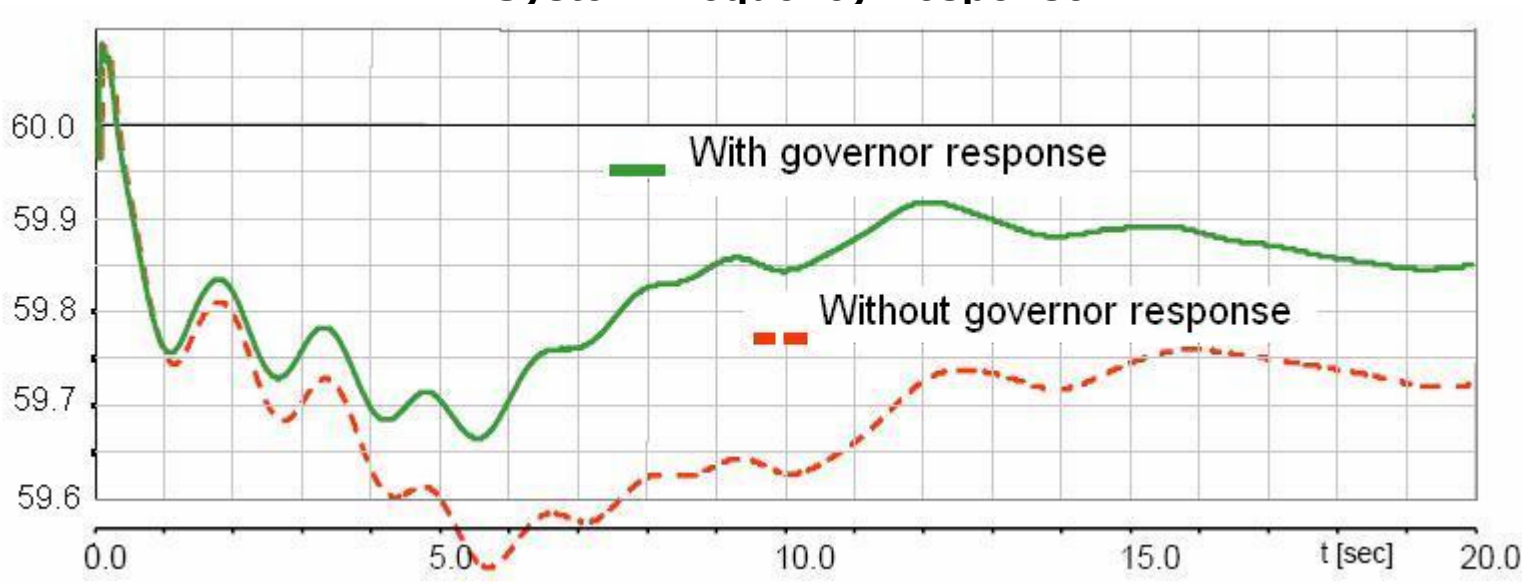
- Non-compliance with WECC standard
- Loss of excessive amounts of generation resources
- Uncoordinated with underfrequency load shedding
- Significantly increased restoration time

Issue: Frequency Deviations (cont.)

Description: Absent governor response, frequency will drop too low and remain low for too long. Un-damped or poorly damped frequency oscillations could cause cascading outages.

Illustrative

System Frequency Response



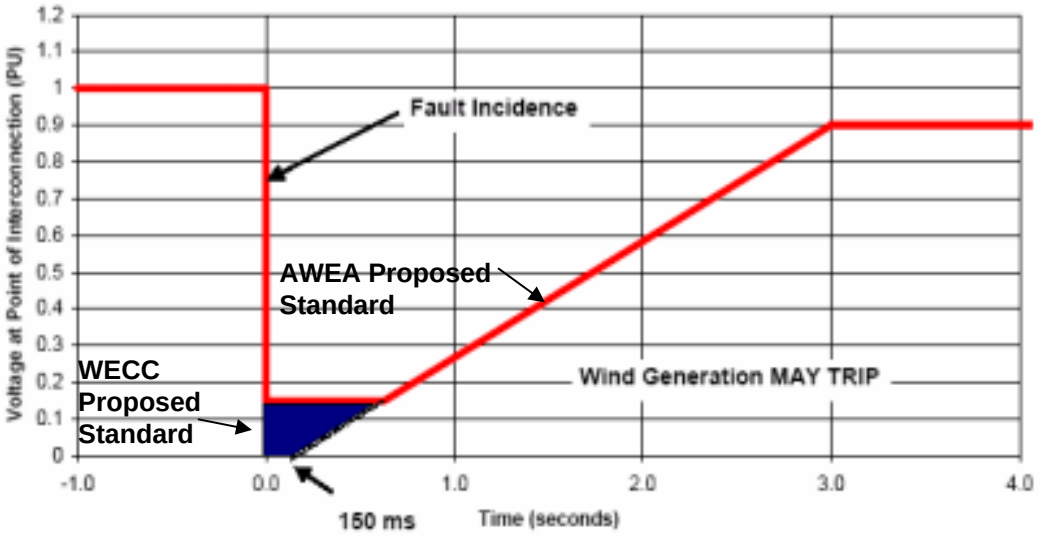
Going forward

- What frequency response capability should be required of renewable generation?

Issue: Voltage

Description: What voltage ride-through performance (grid support) can be expected or requested from renewable generation

Voltage at Point of Interconnection



Source: AWEA Proposed Voltage Ride Through Standard

Standards

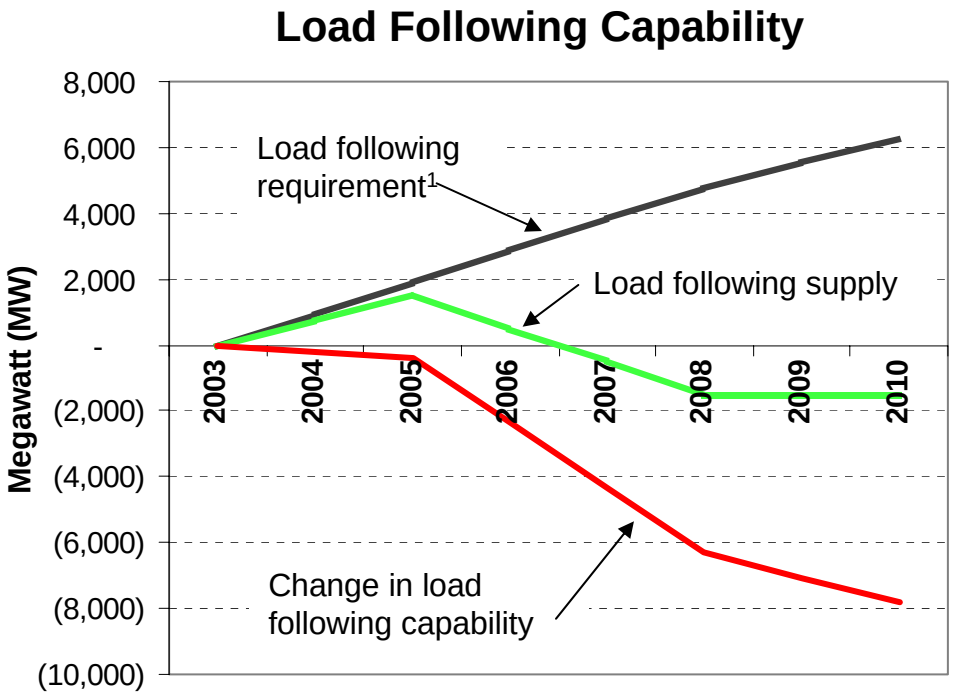
- Ride through
  - WECC, FERC, AWEA, and Alberta ESO have all proposed low voltage ride-through standards
  - WECC proposed standard is more stringent than AWEA, FERC or Alberta standards
- Voltage Support
  - AWEA and Alberta ESO have proposed power factor standards
- E.ON and Eltra have standards

Impacts

- Voltage/VAR control and low voltage ride through are key contributors to grid reliability
- Higher minimum voltage in AWEA/FERC/Alberta standards may restrict size of collector systems (over concern about the amount of generation lost due to a nearby transmission fault)

Issue: California Controllable Unit Retirement

Description: Many of the controllable generators in the present resource mix are possible candidates for retirement. Many new generators are not as readily controllable, such as for load following and ramping services.



[1] Load following requirement includes both load ramp increase and accelerated RPS intermittent resource load following needs

- California controllable units were mostly built in the 1960's
- Many of these units are facing retirement
- Addition of renewables adds to the need for load following, ramping, and control
- Retirement of older steam units also reduces local inertia thereby impacting local voltage supply and reliability
- List of Operating Attributes Provided by Retiring Generation
  - Automatic Generation Control (AGC)
  - Controllability
  - Dependable Start-up Capability
  - Dispatchability
  - Governor Response (Droop)
  - Power System Stabilizer
  - Local Reliability and Voltage Supply
  - Disturbance Response

Issue: Deliverability

Description: Much of California's renewable resources potential are expected to be developed in regions of limited transmission (e.g., Tehachapi, Imperial Valley). As utilities seek to meet the RPS, it is possible that renewable energy may need to be transferred from one part of the state to other parts across key transmission lines.

Going forward:

- Majority of RPS renewables are in Southern CA
- What needs to be done so that the transmission system can adequately ensure deliverability from renewable resources to load serving entities throughout the state

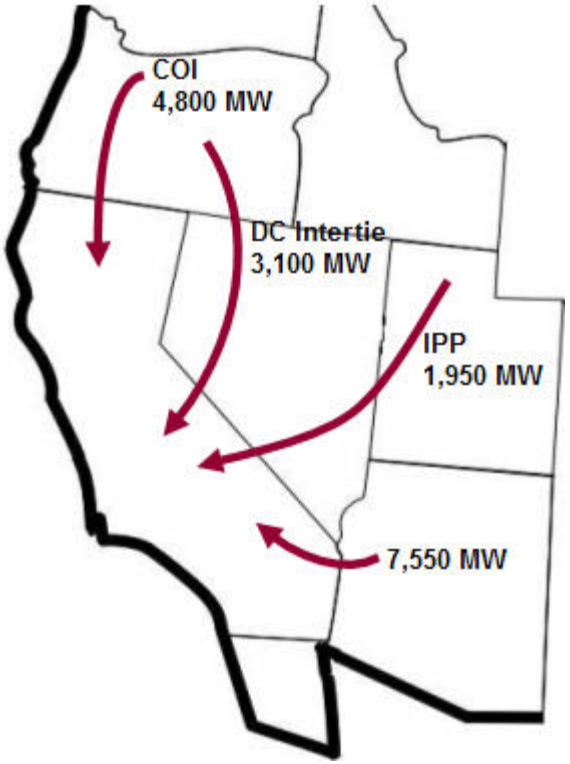
Impacts:

- Full benefit and integration of renewable resources may not be achieved
- Increased transmission congestion

Transmission grid has congestion during peak usage times like the freeway system

Issue: California's Transmission Import Capability and WECC Impacts

Description: Is there the potential for a significant resource mix change in California and other states to have regional implications?



Transmission Path Ratings are Based on:

- Thermal capability of installed facilities.
- Voltage support between source and sink.
- The dynamic performance of generation resources during a likely contingency event.

Impacts:

Change in resource mix could impact transmission path ratings into California and throughout the WECC.

Going forward: What do California and others in the WECC need to do to maintain existing transmission path ratings that could be impacted as a result of significant changes in the regions generation resource mix?

Planning and Modeling

- Most transmission planning is done for peak load day conditions, not peak power transfer conditions
- Need to develop off-peak and shoulder peak WECC study cases in order to study transmission loading patterns
- The planning models don't adequately capture the performance of the wind generators
  - Missing good forecasts of wind production by time of day to build into power flow studies
  - Missing good models for wind generators' dynamic voltage and frequency performance
- Should there be standards for the application of Remedial Action Schemes used to mitigate potential overloads and congestion?
- There is an absence of wind production data available to allow analysis
- There is an absence of meteorological data to support real time wind forecasting

Recap of Issues

Recap of Issues

Load Following (LF) and Ramping

- Current LF demand is significant
- The LF demand is increasing
- Supply is eroding due to new generator attributes and aging plant retirements

Minimum Loads

- High levels of off-peak energy result in operating problems for the CAO, TSO, and LSE
- Exports of our excess may not always be an option
- Managing minimum loads requires off-peak energy production curtailments

Storage

- Storage not available during spring run-off months to mitigate minimum load condition
- Additional storage and load control facilitate integration of intermittent resources

Reserves and Resource Mix

- Intermittent resources require shadow reserves
- Some intermittent resource types do not provide all the required operating attributes for meeting reliability standards

Load and Generation Forecast Variability

- Forecast accuracy affects reserve requirements

Frequency and Voltage Requirements

- Frequency and voltage ride-through standards for new generation may be needed

Retirement Risk of Older Plants

- The need for controllable generation in the state is growing
- Many of the controllable generation units are likely candidates for retirement.

Resource Deliverability

- Full benefit and integration of renewable resources may not be achieved

Transmission Import Capability

- Poor generating performance could negatively impact existing transmission path ratings into CA and throughout the WECC

Planning and Modeling

- Lack of detailed modeling data to support studies
- Lack of off-peak study cases to analyze transmission system loadings

Next Steps

Next Steps

Stakeholders can provide written comment to the CEC by February 15, 2005.

Continuing project work:

1. Summarize and quantify operational issues
2. Review of options (e.g., policies, procedures, standards) that would facilitate the integration of renewable resources
3. Workshop for stakeholder final review – late April
4. Final report recommendations and integration with the CEC's IEPR – June 1, 2005